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Motor coordination as predictor of physical fitness in prepubertal boys

Coordenação motora como preditora da aptidão física de meninos pré-púberes

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Abstract – Motor competence is associated with numerous health-related variables of the pediatric population. The present study aimed to analyze the effect of the level of motor coordination on performance in several physical fitness tests in prepubertal boys, before and after controlling body mass. The sample consisted of 71 Brazilian eight-year-old boys. Anthropometry included stature, body mass and estimates of fat mass and fat-free mass. Biological maturation was evaluated by the percentage of predicted adult stature. The physical tests applied were 2-kg medicineball throw, handgrip strength, sit-ups in 60 seconds, standing long jump, 10x5-m shuttle run, 20-m shuttle run and sit and reach. Motor coordination was assessed by the Körperkoordinationtest für Kinder (KTK). For data analysis, descriptive statistics, Pearson correlation, Student's t-test and ANCOVA were used, with body mass as covariate. Significance level was set at p <0.05. There was no difference in maturational level between the different groups of coordinative performance. The results showed that boys with better performance in motor coordination tests are associated with better results in physical fitness tests, especially those involving body mass displacement. This trend remained even when comparing groups controlling body mass, except for the sit-up test. Therefore, it could be concluded that motor coordination is a predictor of physical fitness in prepubertal boys.

Key words: Child; Motor activity; Motor skills; Physical fitness.

Resumo – *A competência motora está associada a inúmeras variáveis relacionadas à saúde da população pediátrica. O presente estudo teve como objetivo analisar o efeito do nível de coordenação motora no desempenho em diversos testes de aptidão física de meninos pré-púberes, antes e depois de controlar o efeito exercido pela massa corporal. A amostra foi composta por 71 meninos brasileiros com oito anos de idade. A antropometria considerou a estatura, a massa corporal e as estimativas de gordura corporal e de massa magra. A maturação biológica foi avaliada pelo percentual da estatura matura predita. Os testes físicos aplicados foram o lançamento de medicineball 2-kg, preensão manual, abdominais em 60 segundos, salto horizontal, 10x5-m shuttle run, 20-m shuttle run e sentar e alcançar. A coordenação motora foi avaliada pelo Körperkoordinationtest für Kinder (KTK). Para análise dos dados, foi feita a estatística descritiva, a correlação de Pearson, o teste t-Student e a ANCOVA, com a massa corporal como covariável. O nível de significância adotado foi de p<0,05. Não houve diferença quanto ao estado maturacional entre os diferentes grupos de desempenho coordenativo. Os resultados evidenciaram que meninos com melhor desempenho em teste de coordenação motora estão associados aos melhores resultados em testes de aptidão física, nomeadamente naqueles que envolvem deslocamento da massa corporal. Esta tendência permaneceu mesmo quando foi realizada comparação entre ambos os grupos com o controle da massa corporal, com exceção do teste de abdominais. Pode-se concluir que a coordenação motora é preditora da aptidão física em meninos pré-púberes.*

Palavras-chave: *Atividade motora; Aptidão física; Criança; Destreza motora.*

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INTRODUCTION

Motor competence and physical fitness are complex, multidimensional and interrelated concepts whose assessments cannot be summarized to the performance of a single test. Motor competence or motor behavior defines the acquisition and refinement of certain skills, while physical fitness is a state or condition that allows supporting daily activities[1]. Several test batteries have been used in the evaluation of motor skills in children[2]. In this context, the *Körperkoordinationstest für Kinder* (KTK) has been widely used with elementary school children in many countries[3-4]. Physical fitness assessment has recently been used as a health parameter. Test batteries set reference values to achieve healthy benefits[5]. Fjørtoft et al.[6] recommend that a battery of physical fitness tests should include a combination of tasks requiring aerobic endurance, strength, flexibility, agility and balance.

While motor competence typically increases with age and motor experience, children of the same chronological age and/or maturational level, and even of the same sex, may present significant differences in performance[5]. Between 3 and 6 years of age, sex differences regarding motor competence are minimal, both of which demonstrate potential for motor repertoire improvements[7]. From mid to late period that includes the end of childhood and throughout adolescence, boys stand out in motor skills improvements, notably in activities that require muscle speed, strength and muscle power, which contributes to a remarkable differentiation between sexes[5]. Although many of these differences can be attributed to sex and pubertal development, differences that emerge during late childhood and continue throughout adolescence are also a result of sex differences in socialization, which reflect in opportunities for the practice of different physical activities[5]. Physical activity and sports practice have a reciprocal relationship with motor competence throughout childhood and adolescence in both sexes[8-10].

There is evidence in literature that motor coordination and physical fitness interact with physical growth and biological maturation in children and adolescents[11-13]. Some studies have evaluated associations between these domains in the pediatric population[14], specifically in males[15]. However, there is still lack of studies in literature on the effect of coordinative fitness on performance in physical fitness tests in prepubertal children with the control of some variable of morphological dimension that appears to have an effect on commonly performed physical test protocols[5]. In view of the above, the present study aimed to analyze the effect of the level of motor coordination on the performance of prepubertal boys in several physical fitness tests before and after controlling body mass.

METHOD

Ethical aspects

The present study was developed in accordance with international standards for experimentation with humans (Declaration of Helsinki 1975). This is a descriptive cross-sectional study duly approved by the Ethics Research Committee of the Institution, registered under CAAE number 09200413.5.0000.5013.

Sample and procedures

A total of 71 male schoolchildren aged 8.00-8.99 years participated in the study. The exclusion criteria adopted were the omission in the return of the consent term signed by parents / guardians, absence on the day of data collection or some physical inability to perform the battery of physical and motor coordination tests. A percentage of only 14% of the sample practiced sports outside school context activities. All data collection procedures took place on the premises of schools. On the first day, anthropometric measurements were performed. On the second and third days, respectively, physical and the motor coordination tests were performed.

Anthropometry

Body mass (BM), stature (STA) and skinfolds (SF) were evaluated. BM (0.1kg) was measured by digital scale (Techline, São Paulo, Brazil). To measure STA (0.1cm), portable stadiometer was used (Sanny Caprice, São Paulo, Brazil). Subscapular, triceps and leg SFs (1mm) were measured with Lange adipometer (Beta Technology, Santa Cruz, California, USA). Procedures had as reference the instructions proposed by Lohman et al.[16]. In addition, body mass index (BMI) and fat percentage[17] were calculated, which allowed BM fragmentation into fat mass and fat-free mass estimates. The technical error of measurement and the reliability coefficient of anthropometric measures were, respectively, BM (0.6kg, 0.99), STA (0.6cm, 0.98) and SF (1.0-1.4mm; 0.94-0.98).

Chronological age and biological maturation

Chronological age was calculated by the difference between the date of the first moment of observation and the birth date. Biological maturation was estimated as the percentage of predicted adult stature (% PAS)[18]. For calculation, the stature of the biological parents was self-reported. The same procedure has already been adopted by Drenowatz et al.[19]. Current stature was converted into percentage of reached adult stature. The method has moderate relationship with age in young football players[20].

Physical fitness

Physical fitness was evaluated using some tests of the EUROFIT[21] battery such as: standing long jump (SLJ), sit and reach (SEA), handgrip strength test (HGS), 10x5-m shuttle-run (10SR) and 20-m shuttle-run (20SR). They also composed the sit-up battery in 60 seconds (ABD) and simultaneous 2-kg medicineball throw (2BL). The selection of tests sought to cover musculoskeletal and cardiovascular components. Intraclass correlation coefficients for each test, as well as the order in which they were performed, are as follows: 0.79 (2BL); 0.78 (SLJ); 0.87 (HGS); 0.84 (ABD); 0.92 (SEA); 0.76 (10SR) and 0.67 (20SR).

Motor coordination

Motor coordination was assessed by the *Körperkoordinationstest für Kinder* battery (KTK)[22]. This battery has been frequently used in several countries[3], including Brazil[12]. Four tasks were carried out in the following order: walking backward on balance beams (WB), moving sideways on boxes (MS), jumping sideways across a wooden slat (JS), and hopping for height on one leg (HH). The intraclass correlation coefficients for each battery test were as follows: 0.81 (WB), 0.80 (JS), 0.84 (MS) and 0.92 (HH). For purposes of analysis, the z-score was calculated for each KTK task based on the results of the sample itself. The z-score values for each task were summed for the calculation of a general index and the KTK performance was classified as follows: high performance (general index ≥0) and low performance (general index <0).

Data analysis

Descriptive statistic was calculated for all variables and per KTK performance group. The Kolmogorov Smirnov normality test was also applied. Subsequently, Pearson correlation was performed for KTK tasks, morphological variables and physical tests. Then, comparison between performance groups in KTK was performed through the t-Student test. The magnitude of differences was assessed using Cohen's d[23]. Finally, analysis of covariance (ANCOVA) with body mass control was performed to verify the effect of KTK performance on physical fitness. Significance of $p < 0.05$ was adopted in all analyses. The magnitude of correlations was interpreted as follows: trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$) and almost perfect ($r > 0.9$). The SPSS 22.0 software (SPSS, Inc., Chicago, IL) was used in analyses.

RESULTS

Table 1 presents the descriptive results for the total sample. The mean chronological age is 8.52 years. The percentage of reached adult stature at the time of the study was 74.6%.

Table 2 shows a moderate inverse relationship between most KTK tasks and morphological variables, except for fat-free mass in the backward balance ($r = -0.13$, $p = 0.279$) and hopping for height on one leg tasks ($r = -0.14$, $p = 0.255$). Regarding physical tests, the only that did not show correlation with any of KTK tasks were 2-kg medicineball throw and handgrip strength tests ($R = 0.43$, $p < 0.05$), standing long jump ($r = 0.46$, $p < 0.05$), 10x5-m shuttle run ($r = 0.50$; $p < 0.05$) and 20-m shuttle run ($r = 0.55$, $p < 0.05$).

Table 3 shows that there was no difference in chronological age and percentage of predicted adult stature between groups of different coordinative performances. The best performance group in KTK presented lower

Table 1. Descriptive data of the total sample (71 boys) and normality test.

Variables	Mean		Standard deviation	Normality	
	Value	CL 95%		Valor	p
Chronological age (years)	8.52	(8.45; 8.59)	0.30	0.106	<0.05
Predicted adult stature (cm)	173.3	(171.1; 174.7)	6.31	0.096	0.099
PAS percentage (%)	74.6	(74.2; 75.0)	1.6	0.088	0.200
Stature (cm)	131.0	(129.6; 132.3)	5.6	0.046	0.200
Body mass (kg)	31.3	(29.4; 33.2)	7.9	0.127	<0.05
Fat mass (kg)	8.4	(6.9; 9.9)	6.3	0.185	<0.05
Fat-free mass (kg)	22.9	(22.2; 23.6)	2.8	0.068	0.200
2-kg ball throw (cm)	196	(187; 205)	37	0.065	0.200
Handgrip strength (kg.f)	13.9	(12.9; 14.9)	4.2	0.111	<0.05
Sit-ups (rep)	18.0	(15.8; 20.2)	9.3	0.104	0.053
Standing long jump (cm)	98.3	(93.1; 103.4)	21.8	0.072	0.200
10x5-m *shuttle run* (s)	25.8	(25.2; 26.4)	2.5	0.061	0.200
20-m *shuttle run* (m)	312	(273; 352)	166	0.083	0.200
Sit and Reach (cm)	25.1	(23.7; 26.5)	5.9	0.085	0.200
Backward balance (#)	37.7	(34.2; 41.1)	14.5	0.070	0.200
Jumping sideways (#)	33.1	(30.8; 35.4)	9.8	0.079	0.200
Moving sideways (#)	32.6	(31.0; 34.2)	6.8	0.097	0.093
Hopping for height (#)	36.5	(33.6; 39.4)	12.2	0.086	0.200

Note. CL 95% = 95% confidence limit; PAS = Predicted adult stature; rep = repetitions; # = without measure unit.

Table 2. Pearson correlation coefficients between KTK tasks and chronological, morphological and physical fitness variables in prepubertal boys (n = 71).

Variables	KTK							
	Backward balance		Jumping sideways		Moving sideways		Hopping for height	
	r	p	r	p	r	p	r	p
Stature	-0.25	<0.05	-0.47	<0.05	-0.24	<0.05	-0.25	<0.05
Body mass *	-0.38	<0.05	-0.44	<0.05	-0.27	<0.05	-0.33	<0.05
Fat mass *	-0.41	<0.05	-0.41	<0.05	-0.27	<0.05	-0.36	<0.05
Fat-free mass	-0.13	0.279	-0.38	<0.05	-0.24	<0.05	-0.14	0.255
2-kg ball throw	-0.14	0.261	-0.14	0.232	-0.17	0.146	0.04	0.712
Handgrip strength*	-0.05	0.690	-0.14	0.258	0.04	0.726	0.06	0.629
Sit-ups	0.24	<0.05	0.31	<0.05	0.31	<0.05	0.43	<0.05
Standing long jump	0.38	<0.05	0.36	<0.05	0.33	<0.05	0.46	<0.05
10x5-m *shuttle run**	0.25	<0.05	0.30	<0.05	0.17	0.162	0.50	<0.05
20-m *shuttle run**	0.36	<0.05	0.54	<0.05	0.30	<0.05	0.55	<0.05
Sit and Reach	-0.02	0.899	0.30	<0.05	0.21	0.079	0.22	0.063

Note. KTK = Körperkoordinationtest für Kinder; coefficients referring to the 10x5-m shuttle run had their signals reversed because shorter time means better performance; * logarithmic transformation of data for inferential analysis.

stature (t = 2.107, p <0.05, d = 0.50), body mass (t = 2,627, p <0.05, d = 0.59), (t = 2.667, p <0.05, d = 0.52) and fat-free mass values (t = 2.097, p <0.05, d = 0.30), compared to the lowest performance group. The group of best KTK results showed superiority in the great majority of physical tests, with better performances in sit-up in 60 seconds, standing long jump, 10x5-m shuttle run and 20-m shuttle run tests, with magnitudes of effects oscillating between moderate and large ($p < 0.05$, $0.55 < d < 1.06$). The only task in which low-KTK performance participants presented better results was the 2-kg medicine ball throw.

Table 4 shows that the group of best performance in KTK maintains better performance in physical tests, even with body mass control. In the 2-kg medicineball throw task, although there is no significant difference, boys with high KTK performance exceed their peers and in handgrip strength, differences increase in magnitude.

Table 3. Mean (± standard deviation) of KTK performance and comparison between groups to evaluate the influence of motor performance on chronological, morphological and physical fitness variables

Dependent variables	KTK performance		Student t-test		Effect magnitude	
	Low (n=35)	High (n=36)	t	p	*d*	Qualitative
Chronological age (years)	8.48±0.30	8.56±0.30	-1.090	0.279	0.27	small
PAS percentage (%)	74.8±1.8	74.4±1.4	1.051	0.297	0.24	small
Stature (cm)	132.4±5.1	129.6±5.9	2.107	<0.05	0.50	small
Body mass (kg)	33.6±8.6	29.0±6.6	2.627	<0.05	0.59	moderate
Fat mass (kg)	10.0±7.0	6.8±5.1	2.687	<0.05	0.52	moderate
Fat-free mass (kg)	23.6±3.1	22.2±2.4	2.097	<0.05	0.30	small
2-kg ball throw (cm)	201±42	191±31	1.130	0.263	0.27	small
Handgrip strength (kg.f)*	13.8±4.5	14.0±4.0	-0.462	0.646	0.05	trivial
Sit-ups (rep)	15.5±11.0	20.5±6.5	-2.306	<0.05	0.55	moderate
Standing long jump (cm)	88.1±20.4	108.2±18.5	-4.342	<0.05	1.02	large
10x5-m *shuttle run* (s)*	26.7±2.5	25.0±2.3	3.015	<0.05	0.70	moderate
20-m *shuttle run* (m)*	233±123	391±167	-4.522	<0.05	1.06	large
Sit and Reach (cm)	24.0±5.1	26.3±6.5	-1.639	0.106	0.39	small

Note. KTK = Körperkoordinationtest für Kinder; d = Cohen d for effect size; PAS = predicted adult stature; rep = repetitions; * logarithmic transformation of data for inferential analysis.

Table 4. Means (95% confidence limits) for KTK performance and analysis of covariance (ANCOVA) with body mass control to examine the effect on physical fitness.

Dependent Variables	KTK Performance		ANCOVA		
	Low (n=35)	High (n=36)	F	p	η^2p
2-kg ball throw (cm)	194 (184; 205)	197 (186; 207)	0.156	0.694	0.00
Handgrip strength (kg)*	12.9 (11.8; 13.9)	14.9 (13.9; 15.9)	9.029	<0.05	0.11
Sit-ups (rep)	16 (13; 19)	20 (16; 23)	2.278	0.136	0.03
Standing long jump (cm)	87.5 (80.8; 94.3)	108.7 (102.0; 115.3)	19.124	<0.05	0.22
10x5-m *shuttle run* (s)*	26.7 (25.9; 27.5)	25.0 (24.2; 25.8)	7.536	<0.05	0.10
20-m *shuttle run* (m) *	254 (209; 299)	369 (325; 414)	12.344	<0.05	0.15
Sit and Reach (cm)	23.9 (21.9; 25.9)	26.3 (24.3; 28.3)	2.282	0.136	0.03

Note. KTK = Körperkoordinationtest für Kinder; η^2p = partial eta square; rep = repetitions; * logarithmic transformation of data for inferential analysis.

DISCUSSION

The present study showed positive association between KTK tasks and physical tests that have the characteristic of partially or totally displacing body mass. Regarding the comparative analysis between groups of boys with different coordinative fitness, no influence of chronological age and biological maturation was verified. The findings showed that the group with the best KTK performance presented lower values regarding body morphology variables compared to their less fit pairs, being also superior in most physical tests, especially in physical tests characterized by space displacement. Such evidence was found even when body mass was controlled. However, differences between participants with high and low KTK scores in relation to physical fitness decreased, and the effect of dimensions other than body mass could be speculated.

In a review study, Saraiva and Rodrigues[14] reported that coordinative fitness was the factor most related to physical fitness (7 studies), both in children (r = 0.30 to 0.59) and adolescents (r = 0.15 to 0.43). Such evidence has been confirmed in studies published in recent years, in which motor competence has been positively associated with physical fitness[24-25]. The present study revealed that the best KTK scores, either by task or as total score, are associated with better performance in most physical tests. These results are consistent with literature, which points to an inverse relationship between levels of motor coordination and body mass, but a positive correlation with physical performance and perceived motor competence, both in cross-sectional and longitudinal studies[9,26]. In this context, Vandendriessche et al.[15] studied the multivariate relationships between body morphology, biological maturation, physical fitness and motor coordination of 613 Belgian boys at 7, 9 and 11 years of age and the results pointed to an inverse association between morphological domain and coordinative and physical fitness performances, as well as positive association between physical fitness and KTK results. The present study corroborated the findings of Vandendriessche et al.[15], as it confirmed the inverse relationship between anthropometric measures and KTK performance and concluded that the effect of the best coordinative performance was associated, even with body mass control, to the best results of tests, mainly in the standing long jump, 10x5-m shuttle-run and 20-m shuttle-run tests.

Differences between sexes in motor competence, and between individuals of the same sex with different maturational levels, have important implications in the engagement in physical activities. Katzmarzyk et al.[13] suggest that while maturation of the neuromuscular system may positively contribute to the development of motor skills, maturity-related changes in body size and composition may negatively affect performance, particularly in activities involving body mass displacement. However, in the present study, the results showed that, although controlling body mass values and showing no differences between groups regarding chronological age and biological maturation indicator, subjects with better coordinative fitness remained with the best performances in most physical tests. This evidence reinforces the idea that during the first decade of life, particularly in the primary education years, different levels of motor competence of children may be a consequence of factors not only biological, but also behavioral, cultural and environmental[5,11,27-29].

The present study has some limitations: first, the cross-sectional design avoids causal relationships, which should be investigated and confirmed by prospective studies. Second, this study did not include the assessment of habitual physical activity, which is a factor associated with both physical fitness and motor coordination in children[14]. Third, further studies seeking for estimating the allometric coefficients for the different body size descriptors during childhood should be performed. Finally, a somatic indicator of maturational status was used, the percentage of predicted adult stature reached at the time of the study, with stature values self- reported by biological parents. Although the method showed moderate agreement among young football players[20], it seems interesting to evaluate its agreement in pre-pubertal non-athletes.

The results of the present study showed positive association between coordinative competence and the performance in physical fitness tests among pre-pubertal boys, as discussed by Vandendriessche et al.[15]. Moreover, this effect was maintained even when the influence of body mass was attenuated. Such evidence reinforces the results obtained by Robinson et al.[10] regarding the predictive role of motor competence in the health-related physical fitness profile of pre-pubertal children.

CONCLUSION

The understanding of aspects related to the characteristics of an intervention, whose purpose is to develop the physical fitness of children requires the systematic review of their predictors and the specific way in which they are associated in both sexes. This was the context in which the present study was carried out, as it confirmed the important relationship of coordinative competence in the performance of physical fitness tests, regardless of morphological fitness values.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee – Federal University of Alagoas (CAAE 09200413.5.0000.5013) and the protocol was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: LGOL and MJCS. Performed the experiments: LGOL, DHBS, LCBS and ATCJ. Analyzed data: LGOL, TDDL and MJCS. Wrote the paper: LGOL, GAMN, TDDL, DHBS, LCBS and ATCJ and MJCS.

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